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To Mr. G.E. Patterson
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LABORATORY EVALUATION OF SOLAR DOMESTIC WATER HEATING SYSTEM 'X'

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A refrigerant-charged solar domestic water heating system was purchased and installed in the laboratory to assess its thermal performance and reliability. Considerable problems occurred during commissioning. The system was redesigned and made operational, although it had many outages caused primarily by the refrigerant pump. During the months of June and July 1982, the solar contribution of the system to the water heating load was 52%, when it was fully operational. This report includes a general description of the system together with a discussion of the operating experience and the measured thermal performance.

1. INTRODUCTION

The solar water heating system (System 'X') described in this report was the last system evaluated in the laboratory within the framework of Ontario Hydro's solar domestic water heater program. This system, the first of its kind to use a refrigerant as heat transfer fluid, was tested to demonstrate its performance and to evaluate the supplier's installation and field support capability. Considerable problems occurred during commissioning. The original system had a heat pipe type heat exchanger, which was designed to transfer heat from the refrigerant to the potable water in the preheat tank. Due to its location and configuration, the heat exchanger did not function. The system was redesigned and made operational, although it had many outages caused primarily by the refrigerant pump. The major modification consisted of replacing the "heat pipe" type heat exchanger and the storage tank with a copper tube and fin heat exchanger immersed in a preheat tank. Various other changes were

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made from time to time to improve the system operation and performance.

System 'X' was a closed loop "active" system. The liquid refrigerant turned to vapour when heated and collected in the upper manifold where it travelled through a liquid/vapour separator to the heat exchanger/condenser and then into a receiver. Whenever the refrigerant reached a certain level in the receiver it was transferred back to the collectors by the refrigerant pump. The heat (latent and sensible) was transferred to the potable water through a heat exchanger located inside the preheat tank. Complete specifications and details of operation are presented in Appendix A. The actual system testing started in May 1982 and terminated in January 1983.

2. INSTALLATION AND COMMISSIONING

A-frames were provided on the roof of the laboratory for the installation of the collectors. The frames faced true south and were tilted at 50 degrees to the horizontal. A 180 L electric water heater was provided as the backup system and was located inside the laboratory below the collectors.

3. METHOD OF TESTING

Two hundred and twenty seven (227) litres of hot water at 60°C were drawn each day from the system according to a standardized draw schedule. The method of testing was the same as for Systems 'K' and 'M'/1,2/.

4. RESULTS AND DISCUSSION

Refrigerant-charged System 'X' had considerable problems during the testing period. However, when the system was fully operational it performed satisfactorily. The details of the problems encountered and the improvements made have been continuously recorded and documented/3,4,5/. The performance results of the system when it was fully operational (June-July 1982) are shown in Table 1. This test period consisted of approximately one and a half months out of the seven months of system testing (May 1982-January 1983).

TABLE 1

PERFORMANCE SUMMARY FOR SOLAR SYSTEM 'X'
JUNE 18, 1982 - AUGUST 1, 1982*

Solar Energy Available (kWh)**	826
Baseline Electric Tank Load (kWh)	574
Solar Contribution to Baseline Electric Tank Load (kWh)	301
Electric Energy Displaced by Solar (%)	52
Solar System Efficiency (%)	36
Number of Days System Operational	40
Total Number of Days in the Analyzed Period	48

*Performance results when system fully operational.
**Incident on 4.05 m^2 collector aperture.

Solar system efficiency measures the efficiency in collecting solar energy. It is derived by dividing the amount of solar contribution to baseline by the amount of solar energy available.

The following were noted during the testing:

a) A special pump is needed to circulate the refrigerant because of potential cavitation problems.

b) The solar system must be very well designed so that only liquid refrigerant may reach the pump. During the test gaseous refrigerant reached the pump causing cavitation damage.

c) Only fittings that are specially designed for refrigeration systems should be used. Problems occurred during testing when aluminum fittings, not designed for refrigeration installations, were used.

d) The level controller, which controls the cycling of the refrigerant pump, should be installed close to the pumping unit. This will ease the installation and reduce the system cost without changing the basic system operation.

5. CONCLUSIONS

The refrigerant-charged solar system (System 'X') required further work to improve its reliability and durability. Due to the technical problems that occurred during commissioning and the work

involved in redesigning most of the major components, the effective testing period was approximately one and a half months between May 1982 and January 1983. The system performed satisfactorily when it was fully operational. During June and July 1982, the solar contribution to the water heating load was about 52%.

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REFERENCES

1. R. Chen, "Solar Domestic Water Heating Laboratory Tests - Commercial System 'K'," Ontario Hydro Research Division Report No 81-209-K.

2. R. Chen, "Solar Domestic Water Heating Laboratory Tests - Commercial System 'M'," Ontario Hydro Research Division Report No 81-289-K.

3. R.A. Solczyk, Memo to R. Chen, "Solar Test Station System 'X'," Research Division Memorandum File 814.333(P), June 29, 1982.

4. R.A. Solczyk, Memo to R. Chen, "Solar Test Station System 'X'," Research Division Memorandum File 814.333(P), September 15, 1982.

5. R.A. Solczyk, Memo to R. Chen, "Solar Test Station System 'X'," Research Division Memorandum File 814.333(P), November 2, 1982.

APPENDIX A

DESCRIPTION OF SOLAR SYSTEM 'X'

The arrangement of the major components and the system layout are shown in Figures A1 and A2. The following data characterize the system construction and operation.

Collectors:

- Two collectors (4.05 m^2 total collector aperture area)
- Single glazing, low iron tempered glass
- Rolled bond aluminum absorber
- High temperature black paint surface coating
- Fiberglass insulation
- Collectors plumbed in parallel

Working Fluid:

- Heat transfer fluid: Refrigerant R-11

Preheat Tank:

- 303 L stone-lined tank, double walled

Heat Exchanger:

- Copper tube and fin, single wall heat exchanger (immersed in the preheat tank)

Sequence of Operation

The system is charged with refrigerant R-11 until the collectors are 80% full as it can be checked with the sight glass, seen outside between the collectors (Figure A1).

The refrigerant inside the collector begins to boil as solar radiation falls on the panels. A refrigerant mixture moves upward to the separator where liquid and vapour refrigerant are separated. The liquid refrigerant enters the bottom of the collectors while the vapour refrigerant moves to the heat exchanger where it condenses to a liquid.

The heat (latent and sensible) from the refrigerant is transferred to the potable water in the preheat tank through the heat exchanger. The liquid refrigerant enters the receiver where it collects until it reaches a preset high level. When this occurs, the controller activates the pump and transfers the liquid refrigerant from the receiver to the collectors. The refrigerant level in the receiver continues to drop until the level drops below a certain preset low level. At this point the pump shuts off and the cycle is repeated.

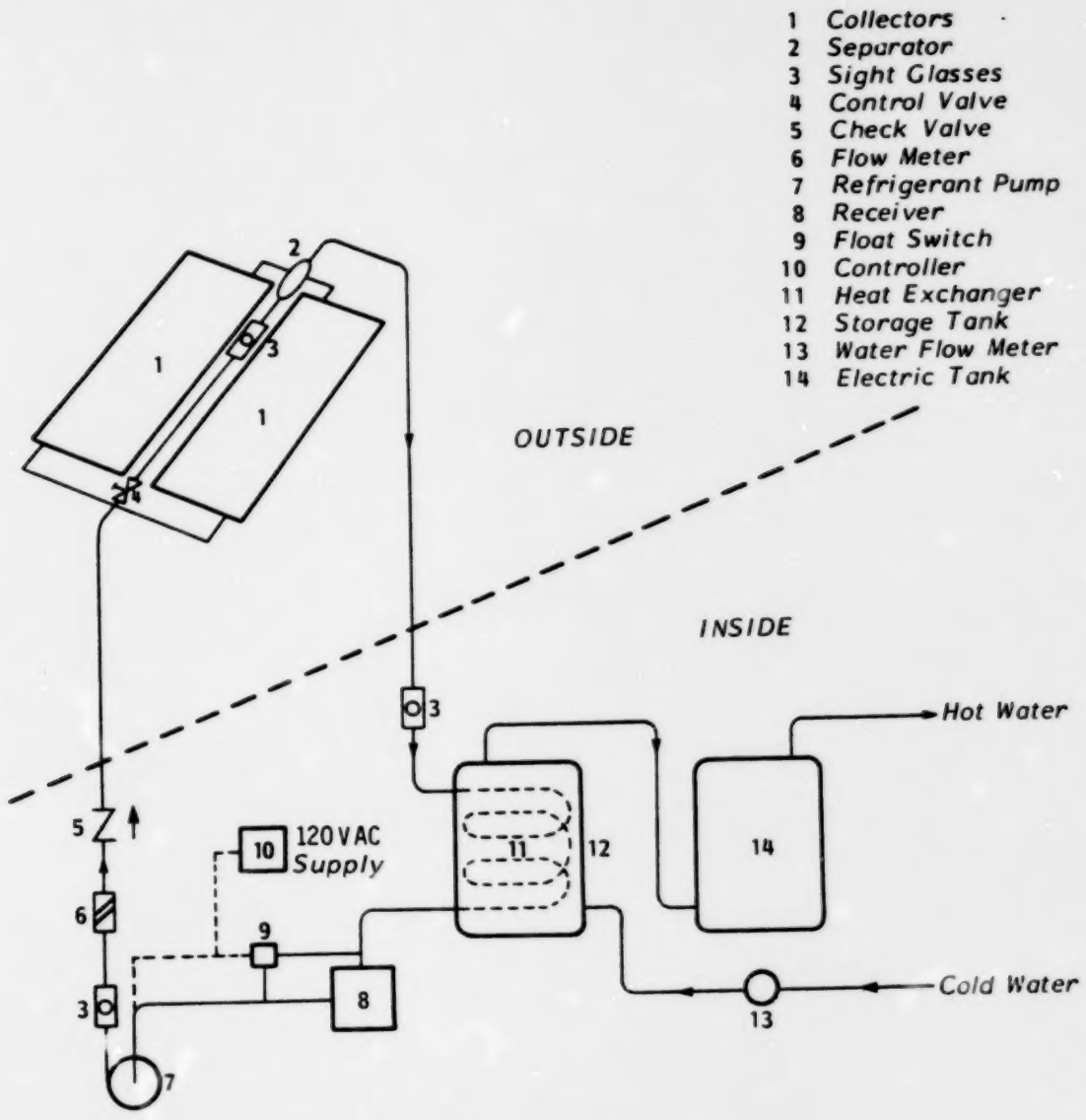

FIGURE A1

SOLAR SYSTEM 'X' - SCHEMATIC DIAGRAM

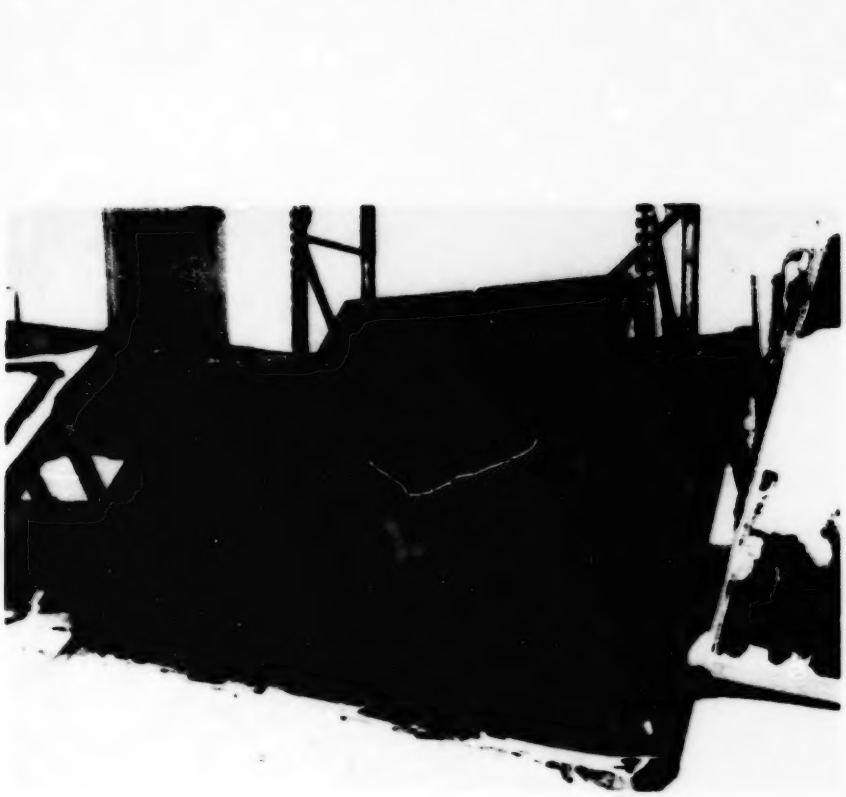

FIGURE A2

SYSTEM 'X': SOLAR COLLECTORS

POOR

QUALITY

ORIGINAL